
The method of description for polished surfaces

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RÉSUMÉ

Nous présentons ici un essai de description objective et quantitative des « polis » d'usage. Fondés sur l'étude des processus de formation, quelques attributs semblant importants ont été choisis : profils, type de répartition, homogénéité, micro-trous, stries, etc. En combinant ces attributs, on décrit des « polis » expérimentaux sans utiliser la nomenclature telle que « poli de végétaux » ou encore « poli de peau » adaptée aux types de matériaux. Il semble qu'il existe une corrélation entre ces attributs et les différents matériaux travaillés. L'informatisation de ce procédé de description et d'identification fournira un système d'identification de « poli d'usage » plus scientifique.

ABSTRACT

This is an attempt to present an objective and quantitative description of « use-wear polish ». Based on the studies of formation process, several attributes which seemed important to describe polished surface were selected, such as profiles, distribution pattern, smoothness, pits, striations, etc. Experimental « polishes » were described by a combination of these attributes, without resorting to such names as « plant polishes » and « hide polishes » after the worked material. The attributes appear to correlate with worked materials. Computerization of this description and identification process will realize a more scientific system of « use-wear polish » identification.

Introduction

This is an attempt to present an objective and quantitative description of polished surfaces. First, we explain the purpose and design of studies, then the method and results are presented. Finally, the prospect of computer image analysis of use-wear surfaces is presented.

Recently, a negative opinion on the high power approach to use-wear analysis has been presented by Newcomer and his colleagues at the London Institute (Newcomer, *et al.*, 1986, Grace 1989). They question whether the « polish » types actually represent worked material types. This has become the most crucial problem in current lithic use-wear studies.

Most researchers agree that the correspondence between different « polish » types, often given names like « plant polish », « bone polish » and the like, do not refer exclusively to actual worked materials. The problem is the actual degree of the correspondence.

Grace (1989 : 60-61) presents the idea that « polish » types cannot be assigned to worked material types as has been believed so far, but rather to the different degrees of « polish » development.

Both those who believe « polish » types reflect worked materials and those who do not use blind tests to support their positions. However, success rates in blind tests depend heavily on the condition of each experiment, so this method cannot directly answer this problem. Rather than depend on such imprecise external methods, the correspondence between « polish » types and worked material types should ideally be measured directly.

There is an initial logical question presented by the high power approach. That is, since « polish » types are named after worked materials, the method confuses description and interpretation. The classification of « polish » should be separated from worked materials, then statistical correspondence between the « polish » types and worked materials should be examined. The researchers of Tohoku University have been using such an approach (Kajiwar, Akoshima, 1981 ; Serizawa, *et al.*, 1981). However, in practice, the definition of each type is not entirely clear and not based on specified attributes, only on vague impressions.

Like Grace (1989) we believe that description should proceed from interpretation, but feel that empirically defined « polish » types do correspond to the materials worked. Furthermore, we agree on Grace's « multi-variate (or multi-dimensional) approach » (Grace, *et al.*, 1988 ; Grace, 1989 ; see also Knutsson's approach to quartz use-wear 1986, 1988a), which suggests that use-wear should be described in terms of several features. Computer image analysis offers an objective means of solving use-wear problems, although the computer analyses carried out so far have not brought the good results we might expect (Grace, *et al.*, 1985 ; Newcomer, *et al.*, 1986 ; Knutsson, 1988b, 1988c). This does not necessarily mean that « polish » types do not represent worked materials, but may only indicate the possibility that the program of analysis was not appropriate. The existing programs which

were developed for other fields have been used for analysis of polished surfaces, but based on published results we could not specify the attributes of polished surface that these programs measured.

For accurate description of polished surfaces, the selection of attributes is the most important problem. Optical « polish » types are not illusions but correspond to actual surface topography of polished surfaces as Yamada demonstrated in this volume. Based on the results, we have selected some attributes which are important for description of polished surfaces.

Although our final goal is to achieve the computerization of measurement and interpretation of polished surfaces, we have not reached that stage. As a primary step, we have prepared visual descriptions of various polished surfaces based on their attributes. We then used those descriptions to examine the correspondence of « polish » and the material worked.

Attributes for describing polished surface

To begin our work, we considered the attributes that are essential for description of polished surfaces with the optical microscope.

Based on the results of previous SEM observation and wear theory on « polish » formation (Yamada in this volume), it is deduced that the hardness, the viscous and elastic properties, and the surface texture of worked materials, have a significant effect on the morphology of polished surfaces ; hard materials such as bone and antler tend to produce flat surfaces, and because of their low viscous and elastic properties polished areas do not develop well in depressions. On the other hand, soft materials such as plant and hide tend to produce domed polished surface which also invade depressions. Therefore, surface *profile* and *invasiveness in depressions* were first chosen as diagnostic features of polished surfaces. We think that one reason why the London Institute partially succeeded in differentiating « polishes » by computer images might be that their programs could measure the *profiles* and *invasiveness in depressions* from gray tone distribution of the images.

We must also specify the scale of observable features. Based on our experience, we have selected

two different scales of features : macro-scale features are identified on the order of 100-200 μm , while the micro-scale features are on the order of 20-30 μm .

For all the following attributes, observations were made at 200x in areas where « polish » was most developed.

Profiles are observed by optical microscope, using the three categories, 1) domed, 2) flat and 3) intermediate (fig. 1). The last one is provided for indistinguishable cases. One reason we describe *profiles* in both macro-scale and micro-scale is to

minimize the influence of the profile of the original surface.

Invasiveness in depressions was observed in the micro-scale only, that is, in features of the order of 20-30 μm , and described as 1) massive, 2) slight or 3) intermediate (fig. 1).

Based on wear theory, we predicted that distribution of the polished area would be affected by the type of worked materials. This is because if the material is hard, the contact area will be restricted. To confirm this, we select *invasiveness from the edge line* (fig. 1), *distribution pattern* and

Attributes	Category	Scale	Causal Factor of worked materials
Invasiveness from edge	1 Edge Only	Macro	Hardness Viscous and elastic properties
	2 < 200 μm		
	3 < 500 μm		
	4 < 1.0 mm		
	5 1.0 mm <		
	6 Away from edge		
Micro profile	1 Domed 2 Intermediate 3 Flat	Micro	Hardness
Micro profile	1 Domed 2 Intermediate 3 Flat	Macro	Hardness
Invasiveness in depressions	1 Massive 2 Intermediate 3 Slight	Micro	Hardness Viscous and elastic properties

0100 μm

Fig. 1. Standard definitions developed for this research (1).

Attributes	Category	Scale	Causal Factor of worked materials
Distribution pattern	1 Extensive	Macro	Hardness Viscous and elastic properties
	2 Linear		
	3 Spotty		
Invasive pattern	1 Distinct	Macro	Hardness Viscous and elastic properties
	2 Intermediate		
	3 Gradual		
Smoothness of polished surface	1 Smooth 2 Intermediate 3 Rough	Macro	Surface texture
Amount of pits	1 Many	Micro	Surface texture
	2 Intermediate		
	3 Few		

Fig. 2. Standard definitions developed for this research (2).

Attributes	Category	Scale	Causal Factor of worked materials
Striation type	1 Filled-in 2 Grooved 3 Linear polish 4 Extremely fine	Micro	Surface texture
Amount of wear	1 Heavy 2 Light 3 Not detected	Macro	Hardness

Fig. 3. Standard definitions developed for this research (3).

invasive pattern (fig. 2). All of these are macro-scale features.

Invasiveness from the edge is the maximum distance of « polish » invasion from the used margin. *Distribution pattern* refers to the horizontal pattern in which a polished area develops. This is also affected by the original surface topography. *Invasive pattern* refers to the transition pattern from the polished to the unaltered area. These three features describe the distribution of the polished area that will as well be affected by the nature of worked materials and the amount of work done.

The surface texture of worked materials will affect such features as *smoothness* of the polished surface, *amount of pits* (fig. 2), and *striation type* (fig. 3).

The *smoothness* of polished area can be deduced as a feature which represents the degree of polishing in micro-scale. This quantity is difficult to measure objectively with the optical microscope.

The *amount of pits* is also considered to be related to the surface texture of worked materials. For example, dry hide working causes many pits. Of course, under the microscope we cannot distinguish pits produced by wear from remnants of original depressions which may have been on the polished area. *Striation type* is described in figures 3 and 8.

Amount of wear refers to the visual degree of macro-scale loss of the edge tip.

We also measured the degree of « *polish* » development which can be affected by the amount of work as well as type of worked materials. This feature also refers to *invasiveness from the edge* and *distribution pattern* listed above. However, to examine Grace’s idea that « *polish* » type relates to the duration of work rather than material type, we select « *polish* » development using Grace’s description.

Results

With these variable definitions, we next examine the actual correspondence of worked materials and the above features on 122 experimental specimens made of siliceous shale.

Through our experiments, we confirmed a clear correspondence between the type of worked materials in all ten attributes categories examined above, that is, 1) *invasiveness from the edge*, 2) *micro-profile*, 3) *macro-profile*, 4) *invasiveness in depressions*, 5) *distribution pattern*, 6) *invasive pattern to edge*, 7) *smoothness*, 8) *amount of pits*, 9) *striation type*, 10) *amount of wear*.

The results are shown in figures 4 to 6, according to worked materials and motions. The tables in figures show the number of experimental specimens showing each category of features. In the case of a cutting/sawing motion, features on both surfaces of edges were counted, so that the number of specimens are doubled.

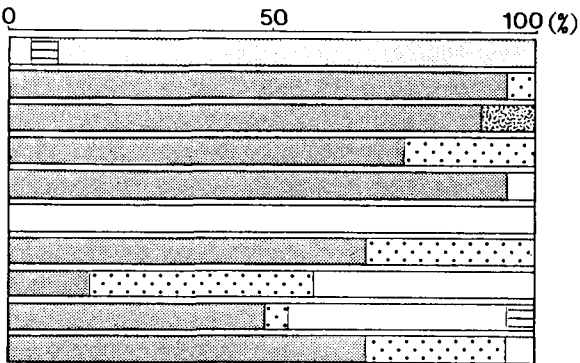
For tools used on non-woody plants, marked *invasiveness from the edge line* is distinctive. Also, *the amount of wear* is large. Other features are similar to those of wood (fig. 4 and 5). For wood working, however, the intermediate type of *invasiveness in depressions* is much more often observed than in the case of non-woody plants. Polished surfaces produced by wood and non-woody plants are similar in their *profiles* and *smoothness*, but different in *distribution pattern* and in *amount of wear* (fig. 5).

Polished surfaces produced by hide are similar to other soft materials in massive *invasiveness in depressions* but different in *smoothness*, *amount of pits* and *grooved* type of striations (fig. 4).

As for bone and antler working, the most distinctive feature is the *profile* of polished surfaces. *Extremely fine* type of striations are also one of the distinctive features of this use. There are also

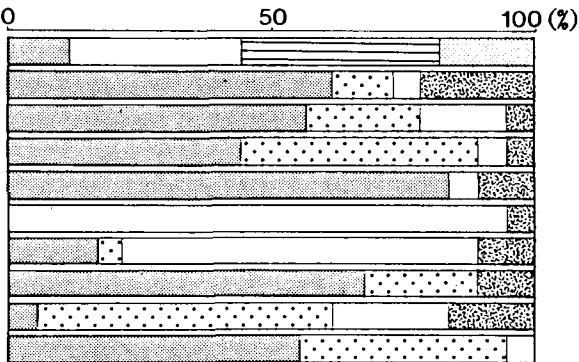
Cutting/Sawing non woody plants. Number of specimens = 11

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	0	0	1	1	19	0	0
Micro profile	20	1	0	-	-	-	0
Macro profile	19	0	0	-	-	-	2
Invasiveness in depressions	16	5	0	-	-	-	0
Distribution pattern	20	0	1	-	-	-	0
Invasive pattern	0	0	21	-	-	-	0
Smoothness of polished surface	14	7	0	-	-	-	0
Amount of pits	3	9	9	-	-	-	0
Striation type	10	1	9	1	-	-	0
Amount of wear	14	6	1	-	-	-	0



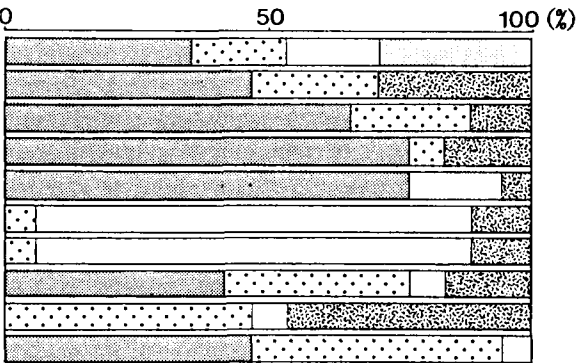
Cutting/Sawing hide. N = 9

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	2	0	6	7	3	0	0
Micro profile	11	2	1	-	-	-	4
Macro profile	10	4	3	-	-	-	1
Invasiveness in depressions	8	8	1	-	-	-	1
Distribution pattern	15	0	1	-	-	-	2
Invasive pattern	0	0	17	-	-	-	1
Smoothness of polished surface	3	1	12	-	-	-	2
Amount of pits	12	4	0	-	-	-	2
Striation type	1	10	4	0	-	-	3
Amount of wear	10	7	1	-	-	-	0



Scraping/Whittling hide. N = 17

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	6	3	3	5	0	0	0
Micro profile	8	4	0	-	-	-	5
Macro profile	11	4	0	-	-	-	2
Invasiveness in depressions	13	1	0	-	-	-	3
Distribution pattern	13	0	3	-	-	-	1
Invasive pattern	0	1	14	-	-	-	2
Smoothness of polished surface	0	1	14	-	-	-	2
Amount of pits	7	6	1	-	-	-	3
Striation type	0	8	1	0	-	-	8
Amount of wear	8	8	1	-	-	-	0



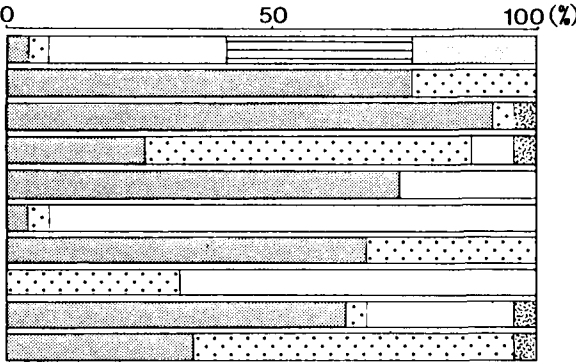
Key

Category	1	2	3	4	5	6	7
Graph							
Invasiveness from edge	Edge only	< 200 μm	< 500 μm	< 1.0 mm	1.0 mm <	Away from edge	Unclear
Micro profile	Domed	Intermediate	Flat				Unclear
Macro profile	Domed	Intermediate	Flat				Unclear
Invasiveness in depressions	Massive	Intermediate	Slight				Unclear
Distribution pattern	Spotty	Linear	Extensive				Unclear
Invasive pattern	Distinct	Intermediate	Gradual				Unclear
Smoothness of polished surface	Smooth	Intermediate	Rough				Unclear
Amount of pits	Many	Intermediate	Few				Unclear
Striation type	Filled-in	Grooved	Linear polish	Extremely fine			Unclear
Amount of wear	Heavy	Light	Not detected				Unclear

Fig. 4. Polished surface features divided according to worked material types (1). Features on both surfaces were counted for edges used in cutting motions.

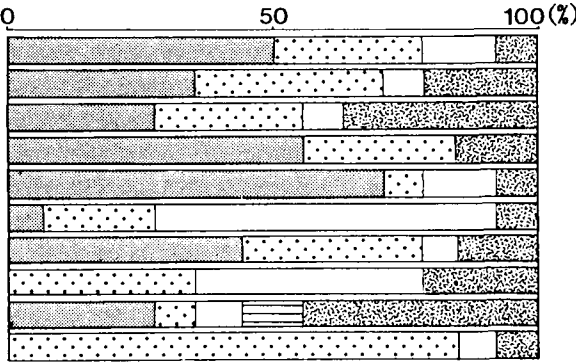
Cutting/Sawing wood. N = 11

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	1	1	7	8	5	0	0
Micro profile	17	5	0	-	-	-	0
Macro profile	20	1	0	-	-	-	1
Invasiveness in depressions	6	13	2	-	-	-	1
Distribution pattern	16	0	6	-	-	-	0
Invasive pattern	1	1	20	-	-	-	0
Smoothness of polished surface	15	7	0	-	-	-	0
Amount of pits	0	7	15	-	-	-	0
Striation type	14	1	6	0	-	-	1
Amount of wear	8	13	0	-	-	-	1



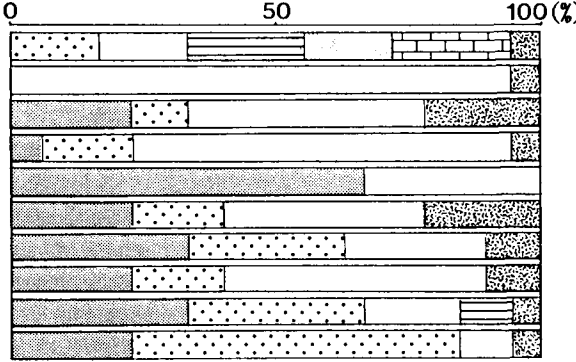
Scraping/Whittling wood. N = 14

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	7	4	2	0	0	0	1
Micro profile	5	5	1	-	-	-	3
Macro profile	4	4	1	-	-	-	5
Invasiveness in depressions	8	4	0	-	-	-	2
Distribution pattern	10	1	2	-	-	-	1
Invasive pattern	1	3	9	-	-	-	1
Smoothness of polished surface	6	5	1	-	-	-	2
Amount of pits	0	5	6	-	-	-	3
Striation type	4	1	1	2	-	-	6
Amount of wear	0	12	1	-	-	-	1



Cutting/Sawing antler. N = 9

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	0	3	3	4	3	4	1
Micro profile	0	0	17	-	-	-	1
Macro profile	4	2	8	-	-	-	4
Invasiveness in depressions	1	3	13	-	-	-	1
Distribution pattern	12	0	6	-	-	-	0
Invasive pattern	4	3	7	-	-	-	4
Smoothness of polished surface	6	5	5	-	-	-	2
Amount of pits	4	3	9	-	-	-	2
Striation type	6	6	3	2	-	-	1
Amount of wear	4	11	2	-	-	-	1



Scraping/Whittling antler. N = 11

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	3	4	1	0	1	2	0
Micro profile	0	0	9	-	-	-	2
Macro profile	0	2	8	-	-	-	1
Invasiveness in depressions	1	0	9	-	-	-	1
Distribution pattern	5	0	5	-	-	-	1
Invasive pattern	4	1	5	-	-	-	1
Smoothness of polished surface	5	3	1	-	-	-	2
Amount of pits	1	2	7	-	-	-	1
Striation type	2	2	1	5	-	-	1
Amount of wear	0	10	1	-	-	-	0

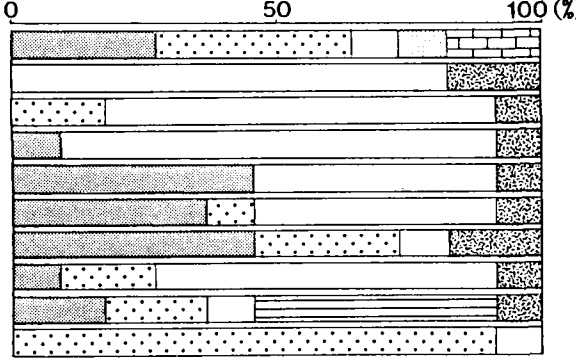


Fig. 5. Polished surface features divided according to worked material types (2). Features on both surfaces were counted for edges used in cutting motions. See key in fig. 4.

differences produced by the cutting motion and the scraping motion. It seems difficult to distinguish bone from antler, based on the features of polished surfaces (fig. 5 and 6).

We did not complete enough experiments on meat to obtain clear results.

Our test offered some insights into the relation between the « polish » development and other features of polished surfaces. Although we have not yet tested the results statistically, we could not observe combinations of features representative of worked material types on undeveloped surfaces (such as A and A+ in Grace's description). However, such features seemed to become clear as the polished surface developed. Therefore, we think that features of polished surfaces are more closely related to the type of worked material than to the duration of work.

Our tests convince us that we can use polished surfaces as an informative evidence of worked materials. Furthermore, if we use the statistical correspondence between the combination of features and worked materials as a base, we will be able to make a more scientific inference of worked materials.

The next step requires development of more objective measures of each attribute through the use of computers and the establishment of a system that makes possible inferences based on the statistical results of experiments.

Perspective of computer image analysis

To realize the complete quantification of the analytical process, we have to develop a computer image analysis program. Since we have just begun to develop it, in this paper, we only introduce the program we are trying to adapt to use-wear research.

The computer system available to us is IP-1000 developed by Asahi-Kasei Incorporated, Japan. We found some of the programs were available for our purposes.

The texture analysis of IP-1000 calculates the texture of an area in terms of gray levels of the image. The development degree of the polished area can therefore easily be calculated with this program.

Cutting/Sawing bone. N = 7

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	2	1	3	3	3	1	1
Micro profile	0	2	11	-	-	-	0
Macro profile	1	3	9	-	-	-	1
Invasiveness in depressions	0	0	13	-	-	-	1
Distribution pattern	7	0	6	-	-	-	1
Invasive pattern	8	3	2	-	-	-	1
Smoothness of polished surface	3	9	1	-	-	-	1
Amount of pits	0	5	8	-	-	-	1
Striation type	5	6	1	1	-	-	1
Amount of wear	3	10	1	-	-	-	0

Scraping/Whittling bone. N = 12

Attributes	Category						
	1	2	3	4	5	6	7
Invasiveness from edge	5	2	1	0	0	2	2
Micro profile	0	1	9	-	-	-	2
Macro profile	1	1	7	-	-	-	3
Invasiveness in depressions	0	3	7	-	-	-	2
Distribution pattern	2	0	8	-	-	-	2
Invasive pattern	7	3	0	-	-	-	2
Smoothness of polished surface	5	5	0	-	-	-	2
Amount of pits	0	1	9	-	-	-	2
Striation type	3	0	0	6	-	-	2
Amount of wear	1	6	2	-	-	-	2

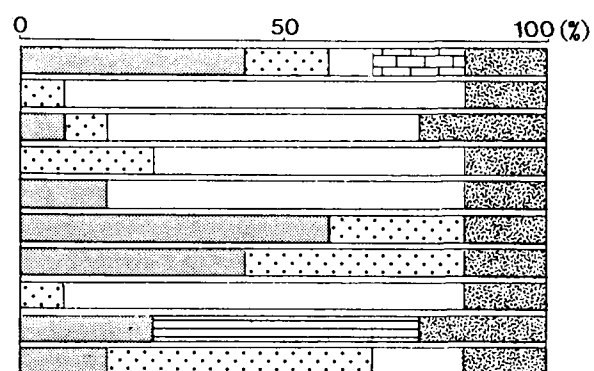
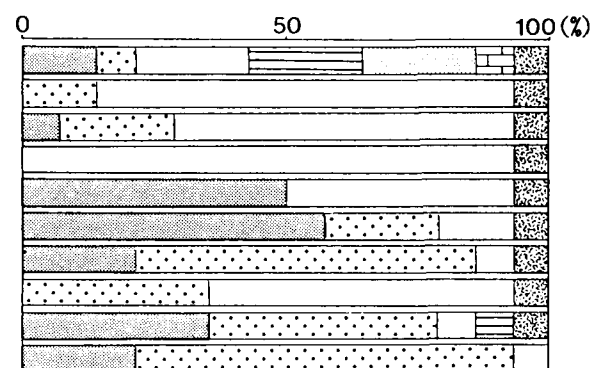


Fig. 6. Polished surface features divided according to worked material types (3). Features on both surface were counted for edges used in cutting motions. See key in fig. 4.

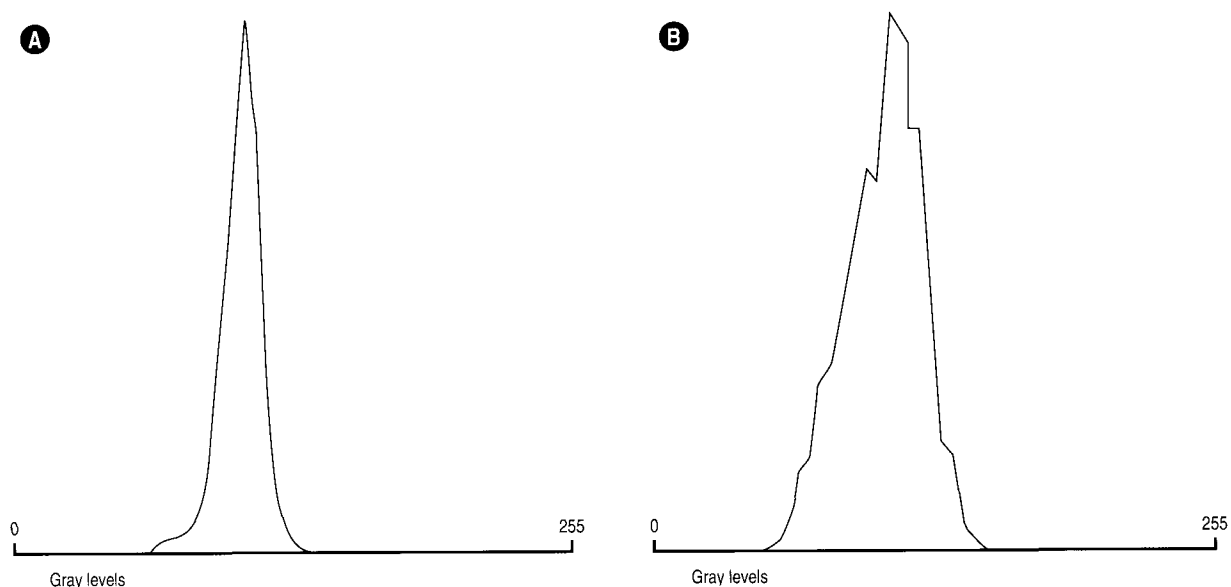
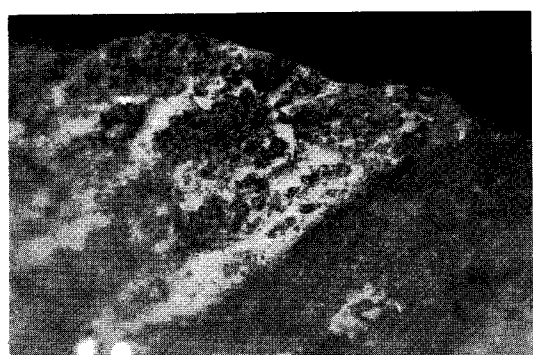
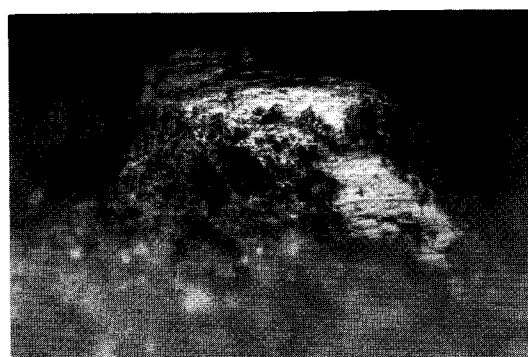


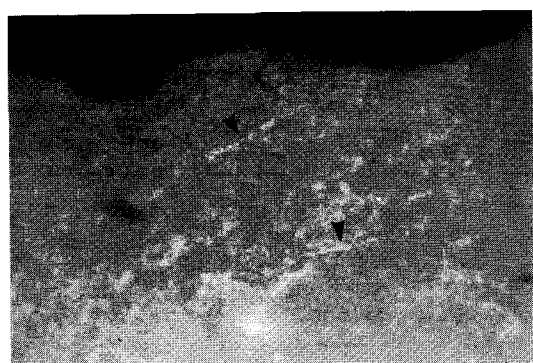
Fig. 7. Histograms of « gray levels » of polished surfaces. This is an alternative way of considering the « smoothness » of polished surfaces. **A.** Smooth. **B.** Rough. These « gray levels » were measured in 25 μm squares.



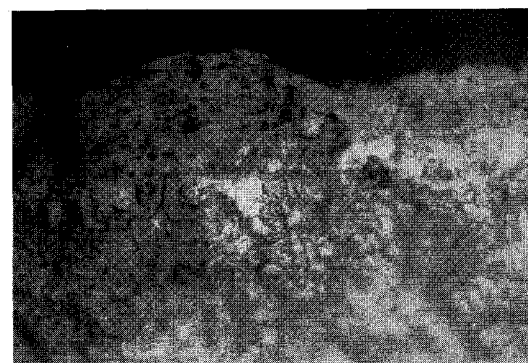
A Sawing wood 100 μm



B Sawing bone 100 μm



C Sawing non woody plants 100 μm



D Scraping bone 100 μm

Fig. 8. Different striation types on experimental tools. **A.** « Filled-in » striation. **B.** « Grooved » striation. **C.** « Linear polish » striation. **D.** « Extremely fine » striation.

The combination of texture analysis and particle analysis of the IP-1000 makes it possible to measure the gray level in a given small area, thus allowing for the measurement of the *profiles*, the *distribution pattern*, the *smoothness* (fig. 7), and the *amount of pits* on a surface.

The tone display makes a graph of gray level along a given line. This makes it possible to evaluate the *distribution pattern* and the *smoothness* of a surface as a supplement to texture analysis.

As stated above, what we are trying to do is to computerize the identification of specified attributes of polished surfaces. We think that utilization of existing programs that do not fully accommodate the nature of polished surfaces is unsatisfactory. Ultimately we need to develop a program especially designed for analysis of polished surfaces.

Conclusion

Some attributes of polished surfaces appear to correlate with worked materials. These attributes include the following : 1) *invasiveness from the edge*, 2) *micro-profiles*, 3) *macro-profiles*, 4) *invasiveness in depressions*, 5) *distribution pattern*, 6) *invasive pattern to edge*, 7) *smoothness*, 8) *amount of pits*, 9) *striation type*, 10) *amount of wear*. We must emphasize that the correlation is imperfect rather than one-to-one. This situation deserves more examination and statistical analysis.

Computerization of this description and identification process will create a more scientific inference system of use-polished surfaces.

Terms like « plant polish » and « hide polish » are not very useful and should, perhaps, be abandoned. Originally, they were thought to be nothing but labels provided for description and convenience. However, as they have developed, they have mistakenly come to be used as if they were actually existent, so that all current discussion cannot be free from misconception. In place of such labeling, it seems more useful to describe worn surfaces of stone tools – in English or French or Japanese – in terms of objective variables that various analyses can recognize and understand. We hope that the variables we have presented here are of that type.

Acknowledgement

The idea of this study was grown out of discussions with Dr Roger Grace, who visited Tohoku University in 1988. It is also based on work which has been developed in the Department of Archaeology at Tohoku University, where use-wear study was introduced in 1978 by Pr Chosuke Serizawa. If our work has merit, it is largely due to the program Pr Serizawa established. We would like to thank Pr Hideaki Takahashi and Dr Kinji Tamagawa, the Institute of Fracture Mechanics at Tohoku University for permission for the use of the image analyzer. We wish to express our thanks to Pr Takashi Sudo for his advice and support, and Pr Peter Bleed for correcting the English of the paper.

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